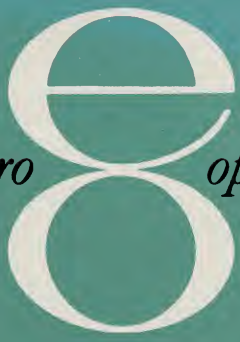

electro optical industries, inc.

A PROGRAM FOR BLACKBODY RADIATION CALCULATIONS

II

Planck's Law Programs for the Texas Instruments model SR-52 programmable calculator

prepared by Ray Chandos

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INTRODUCTION

This booklet includes 2 programs for the Texas Instruments Model SR-52 programmable calculator. These programs transfer the calculation capability of the Electro Optical Industries Inc. blackbody radiation sliderule to the Model SR-52 but with 5 significant figure accuracy.

A copy of the manual for the blackbody sliderule is included since it defines all terms and equations and provides useful examples of the use of the equations.

PROGRAM TITLE:
BLACKBODY RADIATION SLIDERULE

PROGRAM DESCRIPTION, EQUATIONS, VARIABLES:

Planck's expression for hemispherical blackbody flux density radiated in the wavelength interval λ to $\lambda+d\lambda$ is

$$H_\lambda = \frac{c_1}{\lambda^5} \cdot \frac{1}{e^{c_2/\lambda T}-1} \qquad [W/cm^2\text{-}\mu m]$$

where T = blackbody temperature (Kelvins)

c_1 = 37415 $W\text{-}\mu m^4/cm^2$

c_2 = 14388 $\mu m\text{-}K$.

The corresponding expression for photon output is

$$Q_\lambda = \frac{c_1'}{\lambda^4} \cdot \frac{1}{e^{c_2/\lambda T}-1} \qquad [photons/sec\text{-}cm^2\text{-}\mu m]$$

where c_1' = 1.88365×10^{23} $\mu m^3/sec\text{-}cm^2$.

These programs compute

H_λ, Q_λ, $\int_0^\lambda H_\lambda d\lambda$, $\int_0^\lambda Q_\lambda d\lambda$, $\int_\lambda^\infty H_\lambda d\lambda$,

$\int_\lambda^\infty Q_\lambda d\lambda$ given λ and T, $H_{0-\infty} \equiv \int_0^\infty H_\lambda d\lambda$,

$Q_{0-\infty} \equiv \int_0^\infty Q_\lambda d\lambda$ given T, as well as

$T = t_c + 273.15 = 5/9\,(t_f - 32) + 273.15$ given either t_c (Celsius temperature) or t_f (Fahrenheit temperature).

TITLE: BLACKBODY RADIATION SLIDERULE I (Energy)

	◄A► BLACKBODY RADIATION SLIDERULE I		
$H_\lambda (W/cm^2 \mu m)$	$H_{0-\infty} (W/cm^2)$	$\int H_\lambda d\lambda (W/cm^2)$	
$\lambda (\mu m)$	T (K)	$t_c (°C) \rightarrow T$	$t_f (°F) \rightarrow T$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Enter program (A and B)			
2	To calculate H_λ			
	input wavelength λ	$\lambda (\mu m)$	A	
	blackbody temperature T,	T (K) **Note 1**	B	
	compute H_λ		*A′	H_λ ($W/cm^2 - \mu m$)
3	To calculate $H_{0-\infty}$			
	input T	T (K) **Note 1**	A	
	compute $H_{0-\infty}$		*B′	$H_{0-\infty} (W/cm^2)$
4	To calculate $\int H_\lambda d\lambda$			
	input λ	$\lambda (\mu m)$	A	
	input T	T (K) **Note 1**	B	
	compute answer		*C′	$\int H_\lambda d\lambda$ (W/cm^2)
	$= {}_0\int^{\lambda} H_\lambda d\lambda$ if pos.			
	$= {}_\lambda\int^{\infty} H_\lambda d\lambda$ if neg.			

NOTES:

1 Temperature may be entered in °C or °F by pressing C or D, respectively, instead of B.

2 λ and T are stored in memory on entry and need not be re-entered for subsequent calculations.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
$^{000}_{112}$	46	*LBL		01	1		05	5	A λ (μm)
	11	A		04	4		46	*LBL	B T (K)
	42	STO	$^{040}_{152}$	03	3		57	*fix	C t_c(°C)→T
	00	0		08	8		52	EE	D t_f(°C)→T
	01	1		08	8	$^{080}_{192}$	57	*fix	E
$^{005}_{117}$	56	*rtn		55	÷		04	4	A′ H_λ ($W/cm^2 \cdot \mu m$)
	46	*LBL		43	RCL		95	=	B′ $H_{0-\infty}$ (W/cm^2)
	12	B	$^{045}_{157}$	00	0		56	*rtn	C′ $\int H_\lambda d\lambda$ (W/cm^2)
	42	STO		01	1		46	*LBL	D′
	00	0		55	÷	$^{085}_{197}$	17	*B′	E′
$^{010}_{122}$	02	2		43	RCL		43	RCL	REGISTERS
	56	*rtn		00	0		00	0	00
	46	*LBL	$^{050}_{162}$	02	2		02	2	01 λ
	13	C		95	=		45	y^x	02 T
	85	+		42	STO	$^{090}_{202}$	04	4	03 used
$^{015}_{127}$	02	2		00	0		55	÷	04 used
	07	7		03	3		01	1	05 used
	03	3	$^{055}_{167}$	56	*rtn		07	7	06 used
	93	·		46	*LBL		06	6	07
	01	1		16	*A′	$^{095}_{207}$	03	3	08
$^{020}_{132}$	05	5		15	E		07	7	09
	95	=		22	INV		52	EE	10
	41	GTO	$^{060}_{172}$	23	ln x		07	7	11
	12	B		75	–		41	GTO	12
	46	*LBL		01	1	$^{100}_{212}$	57	*fix	13
$^{025}_{137}$	14	D		95	=		46	*LBL	14
	75	–		20	*1/x		18	*C′	15
	03	3	$^{065}_{177}$	65	x		00	0	16
	02	2		03	3		42	STO	17
	95	=		07	7	$^{105}_{217}$	00	0	18
$^{030}_{142}$	65	X		04	4		04	4	19
	05	5		01	1		01	1	FLAGS
	55	÷	$^{070}_{182}$	05	5		42	STO	0
	09	9		55	÷		00	0	1
	41	GTO		43	RCL	$^{110}_{222}$	05	5	2
$^{035}_{147}$	13	C		00	0		15	E	3
	46	*LBL		01	1				4
	15	E	$^{075}_{187}$	45	y^x				

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
$^{000}_{112}$	75	–	0	65	X		75	–	A
	93	.		43	RCL		43	RCL	B
	08	8	$^{040}_{152}$	00	0		00	0	C
	95	=		05	5		04	4	D
	80	*if pos		95	=	$^{080}_{192}$	55	÷	E
$^{005}_{117}$	44	SUM		65	X		01	1	A′
	10	*E′		53	(		44	SUM	B′
	07	7	$^{045}_{157}$	42	STO		00	0	C′
	55	÷		00	0		05	5	D′
	08	8		06	6	$^{085}_{197}$	52	EE	E′
$^{010}_{122}$	04	4		65	X		06	6	REGISTERS
	75	–		53	(		95	=	00
	10	*E′	$^{050}_{162}$	42	STO		80	*if pos	01
	05	5		85	+		44	SUM	02
	95	=		03	3	$^{090}_{202}$	43	RCL	03
$^{015}_{127}$	55	÷		54	)		00	0	04
	06	6		85	+		04	4	05
	00	0	$^{055}_{167}$	06	6		65	X	06
	85	+		54	)		01	1	07
	10	*E′		85	+	$^{095}_{207}$	05	5	08
$^{020}_{132}$	04	4		06	6		55	÷	09
	55	÷		95	=		59	$*\pi$	10
	08	8	$^{060}_{172}$	55	÷		45	y^x	11
	75	–		43	RCL		04	4	12
	10	*E′		00	0	$^{100}_{212}$	65	X	13
$^{025}_{137}$	03	3		05	5		41	GTO	14
	55	÷		45	y^x		17	*B′	15
	03	3	$^{065}_{177}$	04	4		46	*LBL	16
	95	=		55	÷		10	*E′	17
	41	GTO		43	RCL	$^{105}_{217}$	43	RCL	18
$^{030}_{142}$	02	2		06	0		00	0	19
	00	0		06	6		03	3	FLAGS
	05	5	$^{070}_{182}$	22	INV		45	y^x	0
	46	*LBL		23	ln x		56	*rtn	1
	44	SUM		95	=	$^{110}_{222}$			2
$^{035}_{147}$	43	RCL		44	SUM				3
	00	0		00	0				4
	03	3	$^{075}_{187}$	04	4				

TITLE: BLACKBODY RADIATION SLIDERULE II (Photons)

		◄A► BLACKBODY RADIATION SLIDERULE II		
$Q_\lambda\left(\frac{\text{photons}}{\text{sec-cm}^2\,\mu\text{m}}\right)$		$Q_{0-\infty}\left(\frac{\text{photons}}{\text{sec-cm}^2}\right)$	$\int Q_\lambda d\lambda\left(\frac{\text{photons}}{\text{sec-cm}^2}\right)$	
$\lambda\,(\mu\text{m})$		$T\,(K)$	$t_c(°C) \rightarrow T$	$t_f(°F) \rightarrow T$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Enter program (A and B)			
2	To calculate Q_λ			
	input wavelength λ	$\lambda\,(\mu\text{m})$	A	
	blackbody temperature T	T(K) **Note 1**	B	
	compute Q_λ		*A′	$Q_\lambda\left(\frac{\text{photons}}{\text{sec-cm}^2\,\mu\text{m}}\right)$
3	To calculate $Q_{0-\infty}$			
	input T	T(K) **Note 1**	A	
	compute $Q_{0-\infty}$		*B′	$Q_{0-\infty}\left(\frac{\text{photons}}{\text{sec-cm2}}\right)$
4	To calculate $\int Q_\lambda d\lambda$			
	input λ	$\lambda\,(\mu\text{m})$	A	
	input T	T(K) **Note 1**	B	
	compute answer		*C′	$\int Q_\lambda d\lambda\left(\frac{\text{photons}}{\text{sec-cm2}}\right)$
	$= {}_0\int^\lambda Q_\lambda d\lambda$ if pos.			
	$= -{}_\lambda\int^\infty Q_\lambda d\lambda$ if neg.			

NOTES:

1 Temperature may be entered in °C or °F by pressing C or D, respectively, instead of B.

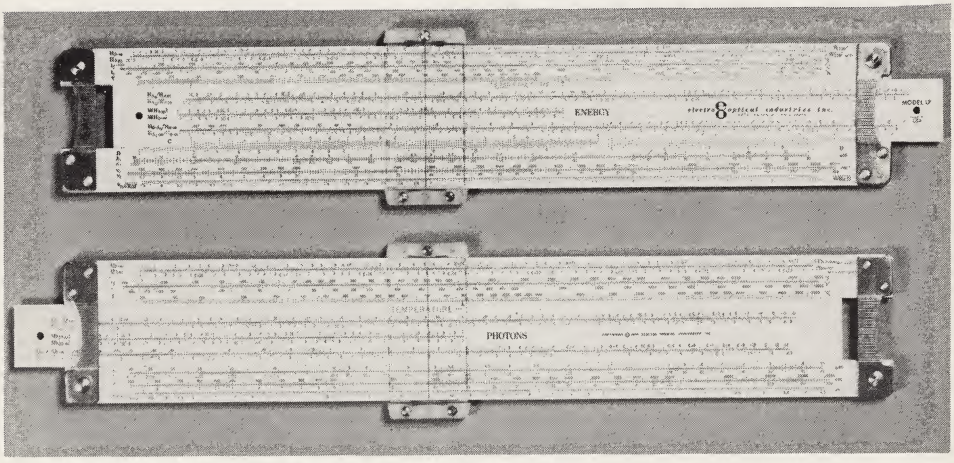
2 λ and T are stored in memory on entry and need not be re-entered for subsequent calculations.

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
$^{000}_{112}$	46	*LBL		01	1		43	RCL	A $\lambda(\mu m)$
	11	A		04	4		00	0	B T(K)
	42	STO	$^{040}_{152}$	03	3		01	1	C $t_c(^\circ C) \rightarrow T$
	00	0		08	8		45	y^x	D $t_f(^\circ F) \rightarrow T$
	01	1		08	8	$^{080}_{192}$	04	4	E
$^{005}_{117}$	56	*rtn		55	÷		46	*LBL	A′ $Q_\lambda \left(\frac{\text{photons}}{\text{sec-cm}^2\text{-}\mu m}\right)$
	46	*LBL		43	RCL		57	*fix	B′ $Q_{0-\infty}\left(\frac{\text{photons}}{\text{sec-cm}^2}\right)$
	12	B	$^{045}_{157}$	00	0		52	EE	C′ $\int Q_\lambda d\lambda \left(\frac{\text{photons}}{\text{sec-cm}^2}\right)$
	42	STO		01	1		57	*fix	D′
	00	0		55	÷	$^{085}_{197}$	04	4	E′
$^{010}_{122}$	02	2		43	RCL		95	=	**REGISTERS**
	56	*rtn		00	0		56	*rtn	00
	46	*LBL	$^{050}_{162}$	02	2		46	*LBL	01 λ
	13	C		95	=		17	*B′	02 T
	85	+		42	STO	$^{090}_{202}$	43	RCL	03 used
$^{015}_{127}$	02	2		00	0		00	0	04 used
	07	7		03	3		02	2	05 used
	03	3	$^{055}_{167}$	56	*rtn		45	y^x	06 used
	93	·		46	*LBL		03	3	07
	01	1		16	*A′	$^{095}_{207}$	65	X	08
$^{020}_{132}$	05	5		15	E		01	1	09
	95	=		22	INV		05	5	10
	41	GTO	$^{060}_{172}$	23	ln x		02	2	11
	12	B		75	−		00	0	12
	46	*LBL		01	1	$^{100}_{212}$	04	4	13
$^{025}_{137}$	14	D		95	=		52	EE	14
	75	−		20	*1/x		07	7	15
	03	3	$^{065}_{177}$	65	X		41	GTO	16
	02	2		01	1		57	*fix	17
	95	=		08	8	$^{105}_{217}$	46	*LBL	18
$^{030}_{142}$	65	X		08	8		18	*C′	19
	05	5		03	3		00	0	**FLAGS**
	55	÷	$^{070}_{182}$	06	6		42	STO	0
	09	9		05	5		00	0	1
	41	GTO		52	EE	$^{110}_{222}$	04	4	2
$^{035}_{147}$	13	C		01	1		01	1	3
	46	*LBL		08	8				4
	15	E	$^{075}_{187}$	55	÷				

LOC	CODE	KEY	LOC	CODE	KEY	LOC	CODE	KEY	LABELS
000 112	42	STO		46	*LBL		00	0	A
	00	0		44	SUM		04	4	B
	05	5	040 152	43	RCL		55	÷	C
	15	E		00	0		01	1	D
	75	–		03	3	080 192	44	SUM	E
005 117	93	.		65	X		00	0	A′
	08	8		43	RCL		05	5	B′
	07	7	045 157	00	0		52	EE	C′
	95	=		05	5		06	6	D′
	80	*if pos		95	=	085 197	95	=	E′
010 122	44	SUM		42	STO		80	*if pos	REGISTERS
	10	*E′		00	0		44	SUM	00
	06	6	050 162	06	6		43	RCL	01
	55	÷		85	+		00	0	02
	09	9		01	1	090 202	04	4	03
015 127	00	0		95	=		55	÷	04
	75	–		40	*x^2		02	2	05
	10	*E′	055 167	85	+		93	.	06
	04	4		01	1		04	4	07
	95	=		95	=	095 207	00	0	08
020 132	55	÷		55	÷		04	4	09
	04	4		43	RCL		01	1	10
	08	8	060 172	00	0		02	2	11
	85	+		05	5		65	X	12
	10	*E′		45	y^x	100 212	41	GTO	13
025 137	03	3		03	3		17	*B′	14
	55	÷		55	÷		46	*LBL	15
	06	6	065 177	43	RCL		10	*E′	16
	75	–		00	0		43	RCL	17
	10	*E′		06	6	105 217	00	0	18
030 142	02	2		22	INV		03	3	19
	55	÷		23	In x		45	y^x	10 FLAGS
	02	2	070 182	95	=		56	*rtn	0
	95	=		44	SUM				1
	41	GTO		00	0	110 222			2
035 147	02	2		04	4				3
	00	0		75	–				4
	03	3	075 187	43	RCL				

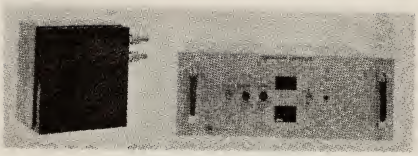
NOTES:

TEXAS INSTRUMENTS' SR-52
PROGRAMMABLE
POCKET-SIZED CALCULATOR

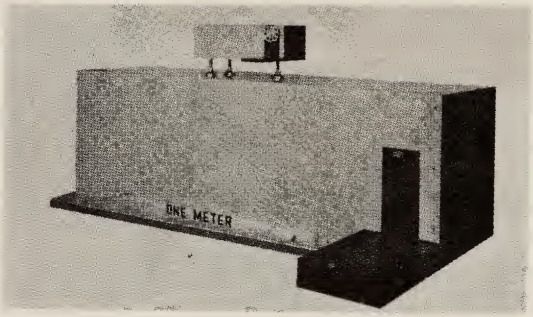


ELECTRO OPTICAL INDUSTRIES'
MODEL 17
RADIATION SLIDERULE

CRYOGENIC VACUUM
BLACKBODIES

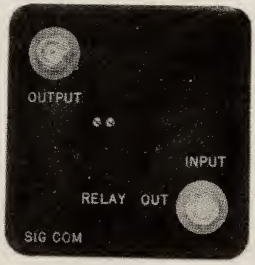


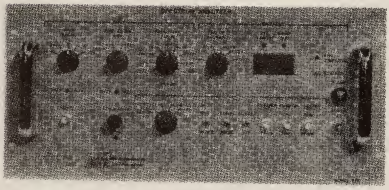
THERMOELECTRIC
DIFFERENTIAL
BLACKBODIES



COLLIMATORS
1 inch to 12 inches

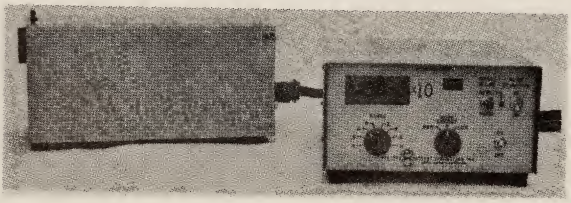
PREAMPLIFIER
low impedance





SPECTRUM ANALYZER
1Hz to 50kHz

SPECTRORADIOMETERS



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